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Development of Young Growth Western Redcedar Stands

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Abstract

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Historical development of western redcedar (*Thuja plicata* Donn) trees and stands, 46 to 58 years old, was analyzed on four upland sites in western Washington.

Keywords: Stand density, silviculture, increment, yield (forest), young-growth stands, western redcedar, *Thuja plicata*.

Summary

Historical development of western redcedar (*Thuja plicata* Donn) stands, 46 to 58 years old, was analyzed on four upland sites in western Washington. Differentiation in height growth occurred at an early age; at age 5, eventual dominants were taller than eventual intermediates. Diameter and volume growth of individual trees were negatively correlated with number of stems per acre. Volume production in these unmanaged, natural stands was comparable to estimated volumes for fully stocked natural stands of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) on these sites but was less than estimated volumes for western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Merchantable yields of western redcedar should be higher in plantations or natural stands with early stocking control. The potential for future management of this species appears excellent.

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Introduction

Western redcedar (*Thuja plicata* Donn) is an important commercial species in old-growth forests of the northwestern United States and Canada. Because the heartwood is workable and durable, redcedar has been utilized for a variety of products and is particularly valuable for exterior uses. In Oregon and Washington, current harvest of redcedar is more than double the annual growth rate (Bolsinger 1979). Value of old-growth cedar has increased to the point that theft of trees and logs is a serious problem. Although cedar products have been produced primarily from old growth, many products are being made from young growth. Values of young-growth cedar logs have increased; in some cases, prices for young-growth redcedar logs have surpassed prices for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Despite such changes in value and the depletion of the old-growth resource, few attempts have been made in the Pacific Northwest to establish plantations or to manage young-growth natural stands of western redcedar. Operational planting has been confined mainly to sites either too wet or too infested with laminated root rot (*Phellinus weirii*) for successful establishment of other conifer species.

There are several reasons for the limited attention devoted to regeneration and management of western redcedar. One is the prevailing opinion that less wood can be produced in young-growth western redcedar stands than can be grown with Douglas-fir or western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). It is also commonly assumed that young-growth redcedar trees will be too fluted, tapered, and limby to make quality wood products. Thus, management of redcedar is intuitively regarded as less profitable (Bolsinger 1979). Research information and operational experience pertaining to stand development, yield potential, and management of young-growth western redcedar are scant. To help fill this void, we studied the present characteristics and analyzed the historical development of four, relatively pure western redcedar stands, aged 46 to 58 years.

Methods

Study Areas

Pure stands of second-growth western redcedar rarely developed after the old-growth coniferous forests in western Washington were logged. We did, however, find four nearly pure, young-growth redcedar stands of 1 to 5 acres each in the foothills of the Cascade Range. Two stands (areas A and B) were at an elevation of 850 feet on the Gordon C. Marckworth Forest (State of Washington Department of Natural Resources) and two (areas C and D) were at an elevation of 1,100 feet on the Pilchuck Tree Farm (Pacific Denkmann Company) (fig. 1). Old-growth stands

in both areas had been logged about 1920, and patches of relatively pure redcedar became established naturally. Annual precipitation averages 45 to 60 inches, most occurring as rain during winter. The soil of area A was an Everett gravelly sandy loam (Dystric Xerochrepts); area B contained an Indianola loamy sand (Dystric Xeropsamments); areas C and D were on Cathcart loam (Andic Xerochrepts). These soils were moderately well drained to well drained, and the areas were more representative of Douglas-fir sites than of the moist to wet sites on which stands containing a large component of redcedar are commonly assumed to grow. Site indices for western redcedar (Kurucz 1978) ranged from 78 to 99 feet. Site indices for other conifers as determined by trees scattered in and around the areas ranged from 106 to 123 feet for Douglas-fir (King 1966) and from 90 to 111 feet for western hemlock (Wiley 1978). Understory vegetation was minimal, and it consisted primarily of vine maple (*Acer circinatum* Pursh), salal (*Gaultheria shallon* Pursh), huckleberry (*Vaccinium* spp.), and occasionally, swordfern (*Polystichum munitum* (Kaulf.) Presl.).



Figure 1.—Location of second-growth western redcedar stands used in study in western Washington.

Sampling Procedures

For information on the average and range in stand characteristics, four rectangular 1/20-acre plots were delineated in each of areas A, B, and C; only two plots were established in area D because this stand was very small. Diameter, height, crown class, taper, and fluting were recorded for each tree on all 14 plots. Cubic-foot (total stem) volumes were estimated from the comprehensive tree volume and tariff tables of Turnbull and others (1972).

Within each plot, three subsampling units of variable size were selected for more intensive study. Each unit was centered around a dominant redcedar tree and was defined by a line drawn midway between the canopy projections of the central dominant cedars and surrounding dominant cedars (Oliver 1978). One redcedar tree in each crown class present in each subsampling unit was measured for total height, diameter, and basal age (increment cores extracted at 1 foot). Thus, specific tree information was gathered on 160 trees—14 plots, three subsampling units per plot, and 3 or 4 trees per subsampling unit.

Two subsampling units in each of the four areas were used for a detailed reconstruction analysis (Henry and Swan 1974; Oliver 1978, 1982). These units were representative of the number, age, and size of dominant trees observed in the overall inventory, and they contained a typical sample of trees of other crown classes in each stand. Searches were conducted on each unit to identify minimum past mortality and to reveal past disturbance (fire, for example) by removing litter (Oliver and Stephens 1977). Then, one tree in each crown class was felled and disks were cut at 0.5 foot, 4.5 feet,

and at 4-foot intervals thereafter. Ring counts and radial measurements taken on these disks were used to determine height, diameter, and volume of the trees at previous times.

Development of the stands and interactions among trees were reconstructed by examining past patterns of height and diameter growth of trees in each crown class. The age at which significant differentiation first occurred was determined by comparing heights and diameters of trees of various crown classes on each subsampling unit at past ages by paired t-tests (Oliver 1978, Wierman and Oliver 1979). Linear regressions were used to ascertain relationships between diameter growth and stand density.

Patterns of volume growth were developed by using the height- and diameter-age data to compute cubic-foot volumes by 5-year intervals with the TREVOL computer program.^{1/} From this information, cumulative and periodic cubic-foot volume growth curves were constructed for individual trees. Past plot volumes for each of the four areas were estimated by assuming that volume growth of present trees in each crown class followed the average pattern displayed in that area by the stem-analyzed trees of the same crown class. Thus, the percentage (fraction) of final volume attained in each preceding 5-year period by sampled trees of each crown class was multiplied by the present total area volumes for each crown class, and the products were summed by period. This procedure underestimates past volumes of lower crown classes by amounts equivalent to mortality losses.

^{1/} Rustagi, Krishna P. 1975. TREVOL computer program. Personal communication. Dr. Rustagi is Associate Professor of Forest Management, College of Forest Resources, University of Washington, Seattle.

Present Stand Characteristics

Representative views of the young-growth redcedar are shown on the cover and in figure 2. Although fluted boles are considered common in redcedar trees grown in the open, in sparsely stocked stands, and in many mixed stands, little fluting was noted in these fully stocked, nearly pure western redcedar stands. Eighty-one percent of the trees were essentially round in cross section at the root collar; another 18 percent were slightly fluted at the base but round at breast height. Thus, 99 percent of the trees were of normal shape at breast height.



Figure 2.—48-year-old second-growth, natural western redcedar stand on well-drained soils in the Marckworth Forest, Washington. When redcedar grows in pure, even-aged stands it produces small-limbed, untapered, unfluted stems and per-acre volumes comparable to natural Douglas-fir.

Other data for each area are given in tables 1 and 2. Stand ages (age of oldest redcedar) ranged from 46 to 58 years. Basal area for the redcedar component of each stand averaged about 260 square feet per acre, ranged from 240 to 290 square feet, and always equaled at least three-fourths of the total basal area. Site index for redcedar (Kurucz 1978) ranged from 78 to 99 feet and redcedar stocking, from 580 to 990 stems per acre; thus, redcedar volumes also varied considerably—6,730 to 8,900 cubic feet per acre.

Stands in all four areas were differentiated into distinct crown classes. Data on specific attributes of each crown class (table 2) provide additional understanding of stand structure in the four areas. Ages of trees in the dominant, codominant, and intermediate crown classes were similar; thus, differentiation among these classes does not appear to be related to time of establishment. The suppressed crown class did include younger trees, however. On the average, 22 percent of the total redcedar stems were dominants, 21 percent were codominants, 28 percent were intermediates, and 29 percent were suppressed. Stand A was the youngest, least dense stand, and it differed most from the above-mentioned average structure. The major differences were a greater proportion of codominant trees (29 percent) and far fewer suppressed trees (15 percent).

Historical Composition of Stands

Numbers and species of trees in the study areas since establishment of the stands were estimated by litter searches on portions of the area. In addition to western redcedar, the selected subsampling units contained evidence of western hemlock, bitter cherry (*Prunus emarginata* Dougl.), and willow (*Salix* spp.). The hardwood species apparently were dominant features of the early stages of vegetation in all areas and in most subsampling units. Much mortality had occurred over the years: more than one-half of all redcedar stems had died; all of the bitter cherry in the litter-searched areas had succumbed and, with one exception, so had the willow. Hemlock had been and still was a significant component in two subsampling units.

Table 1—Site index, age, density, and yield characteristics of young-growth western redcedar stands in 4 study areas in western Washington

Characteristic	Unit of measure	Marckworth Forest		Pillchuck Tree Farm	
		Area A	Area B	Area C	Area D
Site index at breast-high age 50:					
Western redcedar	Feet	99	83	78	82
O Douglas-fir	Feet	118	123	106	106
Western hemlock	Feet	111	104	92	90
Stand age 1/	Years	46	48	58	48
Stems per acre:					
Western redcedar	Number	580	840	710	990
All species	Number	730	1,000	820	1,300
Basal area per acre:					
Western redcedar	Square feet	260	240	290	240
All species	Square feet	320	260	310	320
Cubic volume per acre:					
Western redcedar	Cubic feet	8,900	6,830	8,890	6,730
All species	Cubic feet	10,680	7,090	8,900	7,670
Mean annual volume increment:					
Western redcedar	Cubic feet	193	142	153	140
All species	Cubic feet	232	148	153	160

1/ Age of oldest western redcedar tree.

Table 2—Tree size, age, density, and yield characteristics by crown class of western redcedar in 4 study areas in western Washington

Crown class and characteristic	Unit of measure	Marckworth Forest		Pillchuck Tree Farm	
		Area A	Area B	Area C	Area D
Dominant redcedar:					
Total height	Feet	86.7	75.0	82.8	73.6
Average diameter	Inches	12.7	11.6	14.9	12.1
Stems	Number	150	200	140	180
Cubic volume	Cubic feet	4,680	4,520	5,230	4,340
Age range	Years	43-50	42-48	52-59	41-49
Codominant redcedar:					
Total height	Feet	77.9	68.2	71.2	65.3
Average diameter	Inches	9.2	7.5	9.2	6.7
Stems	Number	170	160	140	160
Cubic volume	Cubic feet	2,640	1,410	1,870	1,110
Age range	Years	43-49	31-48	48-59	41-46
Intermediate redcedar:					
Total height	Feet	69.3	51.3	57.7	58.2
Average diameter	Inches	6.7	5.3	6.5	4.9
Stems	Number	180	200	170	320
Cubic volume	Cubic feet	1,360	780	1,115	980
Age range	Years	42-48	40-47	40-60	41-46
Suppressed redcedar:					
Total height	Feet	48.2	26.4	30.2	26.3
Average diameter	Inches	4.3	2.6	3.0	3.1
Stems	Number	85	275	260	330
Cubic volume	Cubic feet	220	180	260	310
Age range	Years	35-47	32-45	24-56	21-32

The following species were observed in the stands but did not occur on the litter-searched plots. Douglas-fir was common and was dominant where present. Pacific yew (*Taxus brevifolia* Nutt.) occurred as a scattered understory tree with little apparent impact on stand development. Vine maple and red alder (*Alnus rubra* Bong.) were fairly common and may have been important factors in early development and spatial arrangement of stems within the stands.

Height Growth and Differentiation

Average heights of dominant redcedar trees on the four study areas ranged from 73.6 to 86.7 feet. When differences in tree ages are considered, this represents a range of 1.6 to 1.9 feet in mean annual height increment. Trees in lower crown classes were correspondingly shorter and lower in height increment. General patterns of cumulative and periodic height growth of three crown classes are illustrated in figure 3. In general, height growth of all crown classes was relatively slow during the first 5 years; it peaked during the second decade. Thereafter, growth of dominant trees declined slightly to 1.6 feet per year and codominant trees to 1.4 feet; growth has since remained stable. Height growth of intermediate trees, however, has continued to decline. The pattern of growth for suppressed trees is not shown because many rings in the lower bole were missing; thus, curves of height growth to age relationships developed from suppressed tree data would not be accurate. Jackson and Knapp (1914) reported that height growth of redcedar was most rapid between the ages of 10 and 30 years in a thrifty, 80-year-old pure stand and also in a 200-year-old "somewhat suppressed" stand. Although they did not report height-growth patterns by individual crown classes, the trees they examined and those in our study appeared to follow similar height-growth patterns.

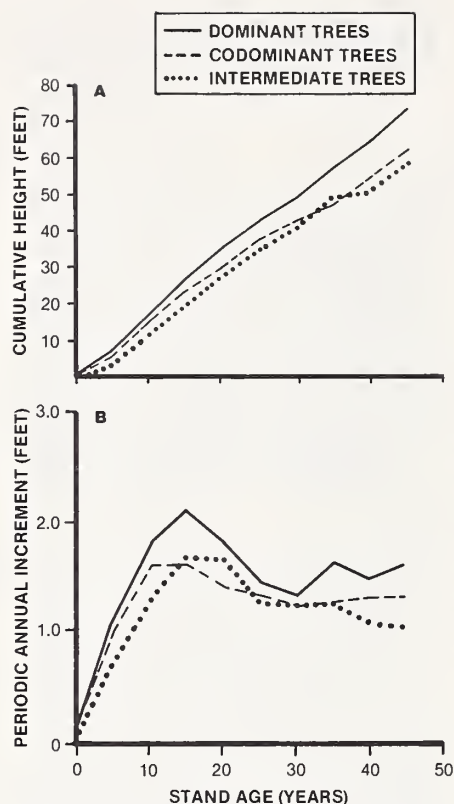


Figure 3.—Average cumulative height and periodic annual height growth patterns for western redcedar trees, by crown class.

There is one important exception to these general statements about height-growth patterns. Cumulative and periodic growth trends for individual trees on all study areas suggest a significant growth depression after the severe freeze of mid-November 1955. This depression is masked in figure 3 because data are averaged by stand age rather than by calendar year. The freeze affected growth patterns of many species in western Washington (Duffield 1956). Evidence of the freeze in redcedar includes crooked stems at the point of the freeze, compartmentalized rot in tips of trees below this point, dead spike tops at crooks that are well below the present terminal, and gaps in age below and above the crooks.

Terminal leaders and portions of the upper stems of many trees apparently were killed by the freeze, and lower branches assumed dominance. As much as 8 feet in attained height of some western redcedar trees may have been lost by the freeze.

Paired t-statistic values showed that eventual intermediate trees were already significantly shorter than dominants by stand age 5; dominants and codominants, however, were not consistently different statistically until after age 25. The long time needed to establish the significance of dominance among taller trees in these stands may be partially caused by the 1955 freeze and changes in crown class associated with it. Nevertheless, these findings suggest that trees to cut or favor in precommercial thinning could be identified with reasonable confidence in pure western redcedar stands between ages 5 and 10 years.

Diameter Growth

General patterns of cumulative and periodic diameter growth are illustrated in figure 4. Diameter increment of all crown classes appeared to peak at about age 15. Growth of dominants has remained fairly stable since age 20, averaging about 0.25 inch per year. Diameter growth of codominant trees declined from age 15 through age 30 and since has averaged about 0.14 inch per year. Growth of intermediate trees has continued to decline. Diameter growth performance of the thrifty young-growth cedar stand studied by Jackson and Knapp (1914) peaked somewhat later (age 25) but averaged about 0.25 inch per year through age 70.

Paired t-statistics showed that diameters of eventual dominant and intermediate trees differed significantly by age 5. Diameters of dominants and codominants, however, were not significantly different during the first 40 years. As with height differentiation, it seems likely that the 1955 freeze and changes associated with it have overshadowed normal trends in diameter differentiation between these two crown classes.

Diameter growth was influenced by stand density. Diameter of dominant trees at age 40 was negatively related to the total number of stems in the past ($r = -0.76$) and to the present number of dominant trees per acre ($r = -0.76$). Such relationships in natural redcedar stands suggest that this species will respond well to wide initial spacing or to early control of density. Best diameter growth of individual trees will occur at density levels considerably lower than those encountered in these natural stands.

Volume Growth (Individual Trees)

Cumulative volume and periodic annual volume growth are illustrated by crown class in figure 5. Volume growth rates of all dominant redcedars examined by stem analysis were still accelerating in the fifth decade after establishment. Volume growth of codominant trees was less than that of dominant trees, but it was also still increasing. Intermediate trees attained their volume growth peak at about age 30 and have since grown at a relatively constant rate.

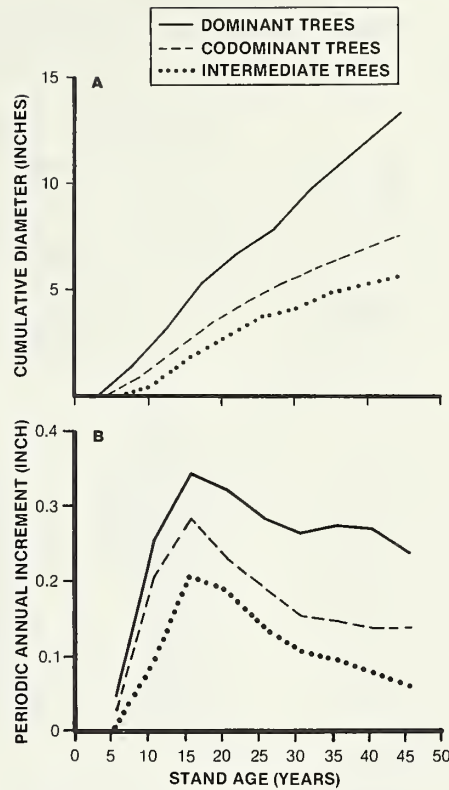


Figure 4.—Average cumulative diameter and periodic annual diameter growth patterns for western redcedar trees, by crown class.

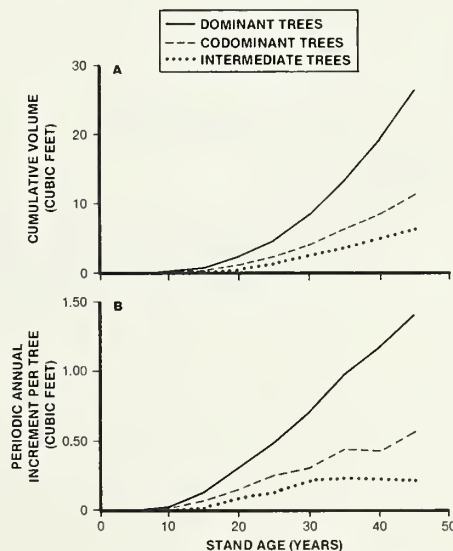


Figure 5.—Mean cumulative volume growth and periodic annual volume growth patterns for western redcedar trees, by crown class.

Stand density also had a strong effect on volume production of dominant trees. Volume at age 40 was negatively correlated with both the total number of stems in the past ($r=-0.76$) and the present number of dominant stems ($r=-0.70$) per acre. Growth of individual trees was greatest at the lowest densities examined, but maximum stand volume production may be attained at higher densities. Tree taper, limbiness, and stem fluting are also likely to increase if spacing becomes too wide.

Volume Growth (Stand)

Table 3 contains estimates of average cumulative volume per acre for the redcedar components of the four study areas. Past volumes, reconstructed by methods described previously, do not include volume produced on trees that died before this study and thus underestimate past cumulative volumes, especially at younger ages. They also exclude volume of other species that occupied growing space in these stands. On the other hand, estimated yields from small plots tend to be higher than yields attainable over larger forest areas (Curtis 1983). British yield tables (Hamilton and Christie 1971) for western redcedar plantations indicate stand volumes after thinning which are comparable to our estimates for sites with similar top heights at 50 years. The data in table 3 provide a reasonable first approximation, and the potential volume production of western redcedar stands appears promising.

Table 3—Estimated average cumulative volume of western redcedar trees in 4 study areas in western Washington

Stand age	Marckworth Forest		Pilchuck Tree Farm	
	Area A	Area B	Area C	Area D
Years	- - - - - Cubic feet per acre - - - - -			
0	0	0	0	0
5	12	10	6	3
10	117	98	53	49
15	471	339	204	240
20	1,085	796	509	681
25	2,075	1,363	1,064	1,304
30	3,185	2,154	1,851	2,110
35	4,659	3,285	2,781	3,815
40	6,247	4,817	3,681	4,488
45	7,886	5,806	4,815	6,053
50	8,900	6,830	6,080	6,730
55			7,565	
60			8,890	

Volume growth trends for redcedar on these small plots are compared with fully stocked Douglas-fir and western hemlock stands for areas A and C, the highest and lowest quality sites studied (fig. 6). Volume estimates for Douglas-fir and hemlock are taken from McArdle and others (1961) and Barnes (1962) after the site index data in table 1 are converted to a 100-year base. Yield of normal western hemlock stands is substantially higher than yield of either western redcedar or Douglas-fir. Early growth of Douglas-fir is more rapid than that of redcedar, but volume production of these two species on 40- to 60-year rotations appears similar. Redcedar's reputation for slow growth compared with growth of Douglas-fir may result from many redcedar trees' having spent much of their early life in subdominant positions. In most natural stands of mixed species that contain western redcedar, the dominant trees are other conifers or red alder; most of these species have faster early growth than redcedar and, except for alder, are long lived. In the areas we studied, the early dominants were primarily short-lived hardwood species such as willows and bitter cherry. In an even-aged plantation with other vegetation controlled, early growth and volume production of western redcedar may be greater than that measured in this study. Comparisons of western redcedar and Douglas-fir in British plantations (Aldous and Low 1974) showed that western redcedar initially grew slower on almost all sites and performed poorly on harsh, exposed upland sites. Generally, however, redcedar became increasingly more productive than Douglas-fir as site class increased; that is, the better the site, the greater the superiority of western redcedar. Of 20 installations on which the two species were compared, cedar outperformed Douglas-fir at 14 installations and was equal to it at 2 installations.

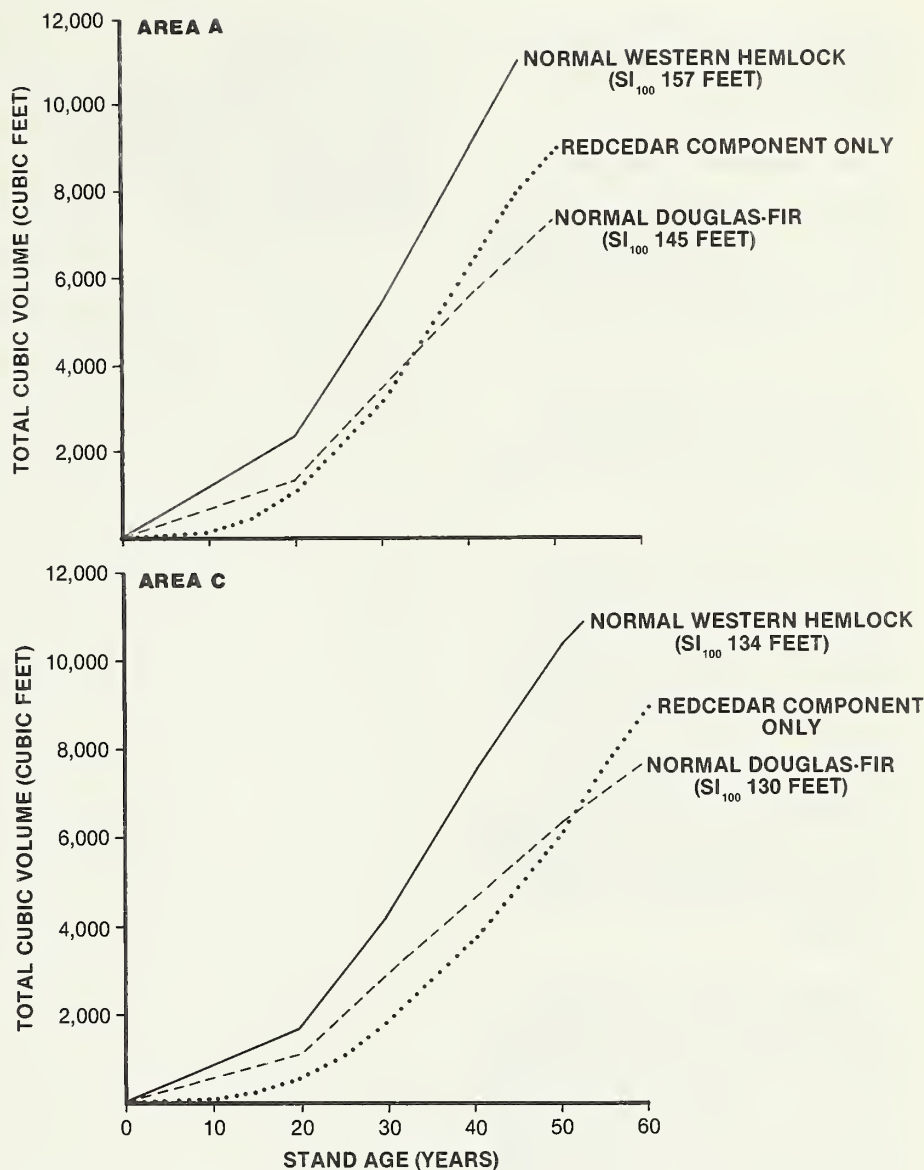


Figure 6.—Comparison of cumulative volume production of western redcedar; estimated normal yields of Douglas-fir and western hemlock.

Conclusions and Management Implications

Our study suggests that young-growth western redcedar has substantial management potential in moist portions of the Douglas-fir region:

1. Productive western redcedar stands can be grown on mesic, well-drained upland sites. Plantings of the species need not be limited to specialty uses as on wet areas or sites infested with root-rot fungi where other conifers are unlikely to produce adequate stands.
2. Diameter and volume growth of individual trees were negatively related to stocking levels. In well-spaced plantations or precommercially thinned natural stands, growth may be higher than that reported here.
3. Stand differentiation began at an early age. By year 5, eventual dominants were significantly larger in both height and diameter than eventual intermediates. Significant differences in height between eventual dominants and codominants did not occur until age 25, but damaging effects of a severe freeze in 1955 may have disrupted normal differentiation patterns. Trees to cut or favor in precommercial thinning could be selected with reasonable confidence by age 10 (or when tallest trees in the stand are about 15 feet tall).
4. Estimated yields of pure western redcedar stands on 40- to 60-year rotations appear at least comparable to "normal" yields for Douglas-fir but less than "normal" yields for western hemlock on the sites we studied. Site index (age 50) was less for redcedar than for the other species, but redcedar stands had more basal area than did Douglas-fir stands.

Metric Equivalents

- 1 inch = 2.54 centimeters
- 1 foot = 0.3048 meter
- 1 acre = 0.4047 hectare
- 1 tree/acre = 2.471 trees/hectare
- 1 square foot/acre = 0.2296 square meter/hectare
- 1 cubic foot/acre = 0.06997 cubic meter/hectare

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